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RESULTS OF RADIO EMISSION OBSERVATION FROM THE PLANET MARS ACCORDING TO DATA OF THE EXPERIMENT ON THE "MARS-3" AUTOMATIC SPACE STATION

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16. Abstract

The Mars-3 planetary probe was equipped with an automatically operating radiotelescope and a radiometer to measure the brightness temperature of the planet at the 3.4 cm wavelength. During the period from December 1971 to February 1972, the radiometer performed six measurement sessions. The data-processing results of the values for effective surface temperature and dielectric constant of the surface material are presented in three sets of curves in this paper. They show that the dielectric constant varies from 2 to 7 with a 3.5 average value, which corresponds to 1.1 to 1.9 g/cm^3 density of martian rock. Temperature variations from approximately 190°°K to 240 °K are also observed.

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RESULTS OF RADIO EMISSION OBSERVATION FROM THE PLANET MARS ACCORDING TO DATA OF THE EXPERIMENT ON THE "MARS-3" AUTOMATIC SPACE STATION

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Radioastronomical measurements of Mars make it possible to /803* study the temperature and permittivity of the surface layers of the planet. A substantial limitation of ground radioastronomical observations is the small resolving power. Even with the largest ground radiotelescopes, it is possible to measure only the mean brightness temperature along the disk and to determine the parameters which are average for the whole hemisphere visible from the earth. In order to obtain comparative characteristics of the various regions of Mars, however, there is required a radiotelescope the dimensions of which cannot be realized on the basis of modern technology. But in making measurements from a fly-past or orbital apparatus, sufficiently high resolution may be obtained with the aid of a radiotelescope of small dimensions.

On the automatic interplanetary station "Mars-3," put into an artificial Mars satellite orbit, an automatically operating radiotelescope was set up with antenna diameter of 0.6 m, designed to measure the brightness temperature of the natural radio emission of the planet at a wavelength of λ=3.4 cm in two linear orthogonal polarizations. The scheme of the radiometer envisaged the formation at the outlet of a voltage proportional

*Numbers in the margin indicate pagination in the foreign text.

to the sum and the difference of intensities of radio emission in the indicated polarizations.

The antenna of the radiotelescope was rigidly attached to the body of the orbital apparatus (OA). The orientation of the electrical axis of the radiotelescope coincided with the orientation of the optical axes of the instruments for measurements in optical and infrared ranges. The trail of the axis on the surface for each broadcast was presented in work [1]. The width of the antenna directivity pattern of the radiotelescope according to the level of half-power was $\sim 4°$. In the region of periares of the orbit, the linear resolution along the surface was $\sim$ 100 km.

The sensitivity of the radiometer was $\sim 1°$ K with a constant period of 1 sec. The radiometer was switched on before the OA passed through the periares of the orbit, the length of each measurement session was $\sim$ 25 min. During the period from December 1971 through February 1972 six measurement sessions were made: December 15 and 27, 1971; January 9, 1972; November 3, 16, and 28, 1972.

For calibration of the intensity of the radiation being received, the switching on of the approved charge instead of the support speaker was stipulated. The orientation of the support speaker was chosen in such a manner as to exclude its direction to the planet and to the sun.

Preliminary data from processing of the results of measurements according to two sessions were published in [2]. In this work, the results of processing for all six sessions are presented.

For a smooth surface in comparison with a long surface wave, the emissivity is determined by the formulas of Fresnel. Therefore, supposing that the surface layer is homogeneous in depth, we have the following relationships for the half-sum T_{as} and the difference T_{ad} of the antenna temperatures in the two orthogonal polarizations:

$$T_{as}={}^1/_2T(E_{\parallel}+E_{\perp})(1-\beta); \qquad T_{ad}=T(E_{\parallel}-E_{\perp})(1-\beta),$$

where $E_{\parallel}$ and $E_{\perp}$ are the emissivities of the surface in two orthogonal polarizations:

$$E_{\parallel}=\frac{4\varepsilon\cos\theta\sqrt{\varepsilon-\sin^2\theta}}{(\varepsilon\cos\theta+\sqrt{\varepsilon-\sin^2\theta})^2}\cos^2\gamma+\frac{4\cos\theta\sqrt{\varepsilon-\sin^2\theta}}{(\cos\theta+\sqrt{\varepsilon-\sin^2\theta})^2}\sin^2\gamma,$$

$$E_{\perp}=\frac{4\varepsilon\cos\theta\sqrt{\varepsilon-\sin^2\theta}}{(\varepsilon\cos\theta+\sqrt{\varepsilon-\sin^2\theta})^2}\sin^2\gamma+\frac{4\cos\theta\sqrt{\varepsilon-\sin^2\theta}}{(\cos\theta+\sqrt{\varepsilon-\sin^2\theta})^2},$$

T is the effective temperature of the surface, ε is the permittivity, β is the coefficient of dispersion of the antenna directivity pattern outside of the main and near side lobes, θ is the angle between the direction of the local normal and the electrical axis of the antenna, γ is the angle between the orientation of polarization of the antenna and the direction of vertical polarization.

The angles θ and γ are determined by conditions of the geometry of measurements in each broadcast, the size of β known according to data of the antenna measurements. According to the measurements of the size of T_{as} and T_{ad} at the observation point, the two unknowns T and ε were determined. The temperature determined as a result of our measurements is the effective temperature emission of the surface at the given wave:

$$T=\int_0^\infty T(y)\,\frac{k(\lambda)}{\cos\theta'}\exp[-k(\lambda)\,y/\cos\theta']\,dy,\quad k(\lambda)\text{ is}$$

the coefficient of absorption of electromagnetic emission. This temperature is approximately equal to the kinetic temperature at a depth $\ell_e = 1/k(\lambda)$ of penetration of the electromagnetic wave [3]. According to data of ground radioastronomical measurements [4,5], $\ell_e = (4-10)\,l_t\lambda$, where l_t is the depth of penetration of the daily heat wave. Thus it may be considered that our measurements of temperature refer to a depth of $\ell_e = (14-34)\ell_t$, $\ell_t = 3-5.5$ cm.

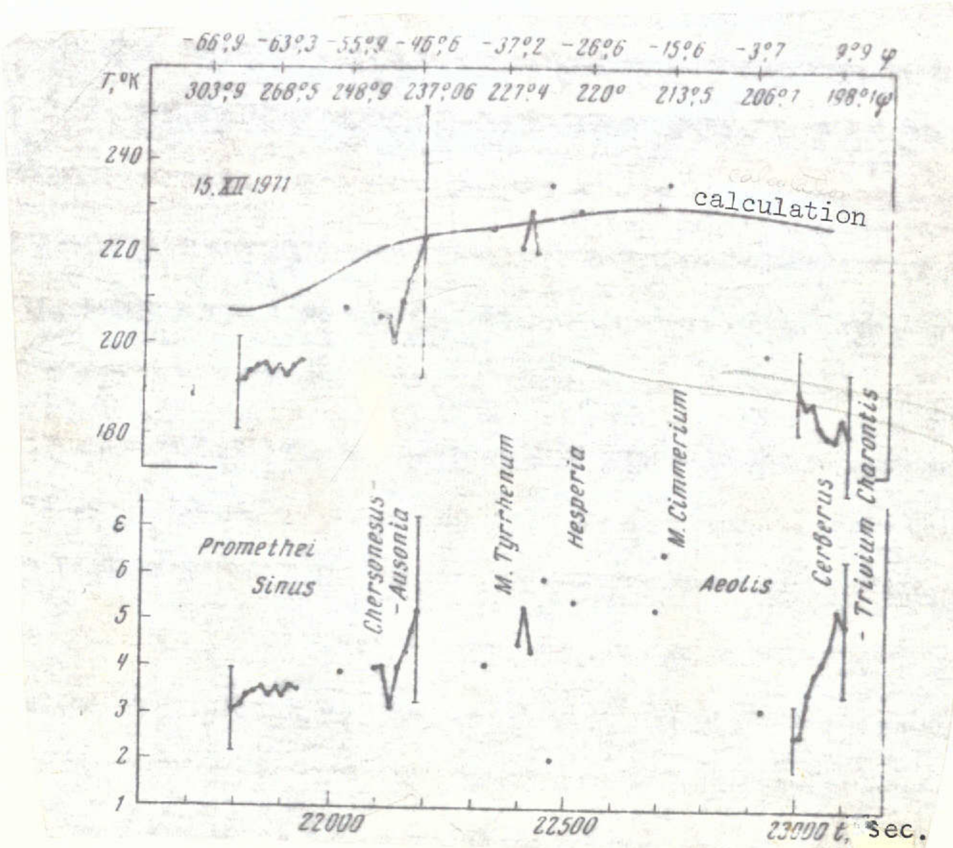

Fig. 1. Dependence of ε and T on time of measurements. Session of December 15, 1971.

The results of determination of ε and T according to the measured sum and difference in intensities of radio emission are presented in Figs. 1-3 for all measurement sessions, except for the session of February 3, 1972, the measurements of which were completed earlier than was planned. In addition, the data of measurements were averaged for a time interval of 15 sec.

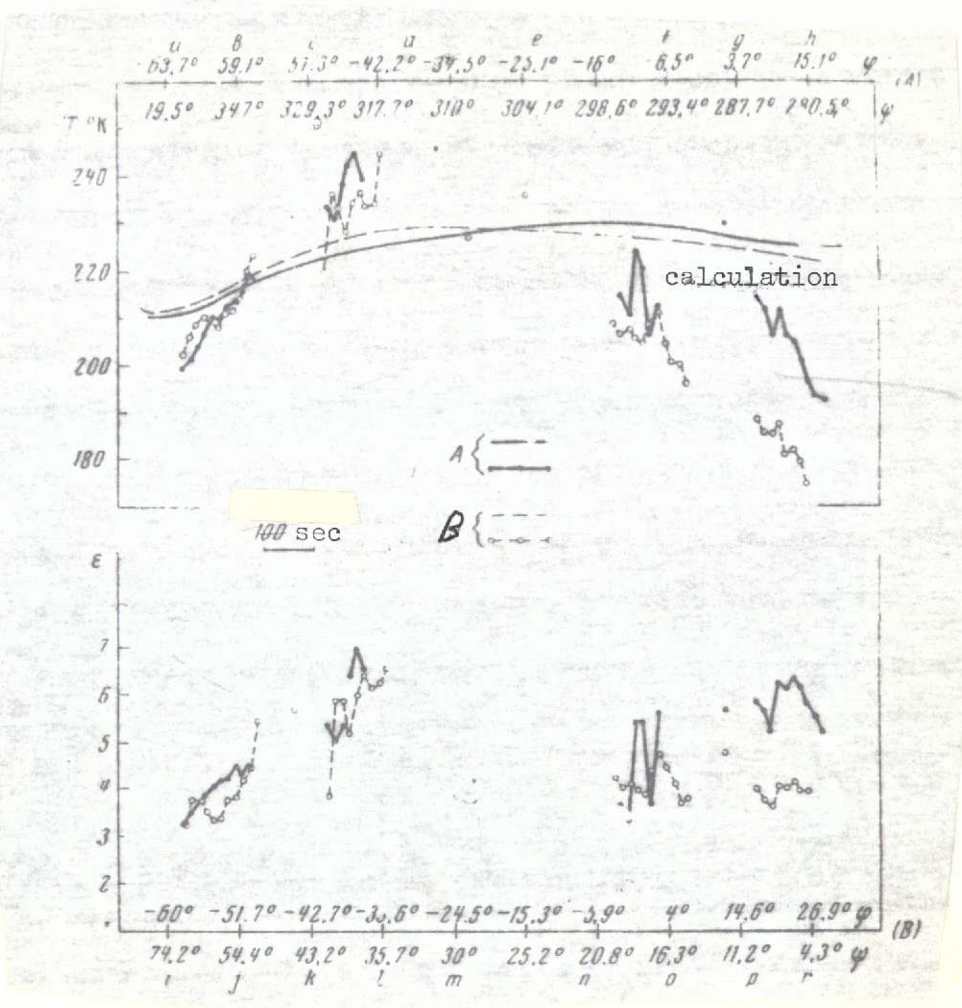

Fig. 2. Dependence of ε and T on time of measurements. Sessions of December 27, 1971 (A) and February 9, 1972 (B).

a - Mare Australe; b - Depressio Hellespontica, c - Hellespontus, d - Yaonis Reg., e - Iapagia, f - Denotria Crocea, g - Syrtis Major, h - Isidis Regio. i - Mare Australe, j - Nereidum Fretum, k - Argyre I, l - Mare Erythraem, m - Pyrrhae Regio, n - Margaritifer Sinus, o - Aram-Oxia Palus, p - Oxia-Thymiamata, r - Deuteronilus

The permittivity of a substance of the surface layer accord- /805 according to data from six sessions changes within the limits of 2-7. The average amount of ε of the Martian soil along the trail of the antenna was $\varepsilon = 3.5$, which is higher than the average ε for the lunar surface in the same range of waves. The amount of ε obtained by us corresponds to the density of Martian rocks $\rho = 1.1\text{-}1.9$ g/cm³ [6].

Maximum amounts of permittivity were obtained both in the dark and in the light regions: Syrtis Major (dark), Cerberus (dark), Mare Erythraeum (dark), Ausonia (light), Isidis Regio (light). Minimal amounts were noted in the regions of: Aeolis (light), Nereidum Fretum (dark), Merroe (light).

Determination of the permittivity was made on the supposition of a smooth, spherical surface. Calculation of the possible roughness or large-dimension inclinations may change the indicated amounts of ε.

The measurements made revealed a broad dependency of temperature for all six sessions. For conditions of measurements of each session, besides that of February 28, 1972, the expected dependencies of the effective temperature on time for $l_e/l_t\lambda = 10$ were calculated. The distribution of temperature along the surface and in depth was found by numerical solution of the equation of thermal conductivity with constant coefficients. A stable solution was obtained, taking into consideration the daily and orbital revolution of Mars for several Martian summers with an amount of the parameter of thermal lag of 0.005. Comparison of the measured and computed amounts of temperature shows that the temperature determined as a result of experiment is basically close to the calculated temperature. Decrease in temperature /806
toward the dial may be caused by inaccurate knowledge of the level of the side lobes or by the chosen model of a smooth surface with a homogeneous surface layer.

As a result of measurements, variations of temperature from field to field were discovered. Regions were noted where local amounts of effective temperatures differ from the average latitude amounts by an amount of up to 10-15°K. In addition, some correlation is also observed between local variations of temperature and permittivity regarding average amounts of these parameters. Regions with greater amounts of ε have, as a rule, a higher temperature. These characteristics require additional investigations.

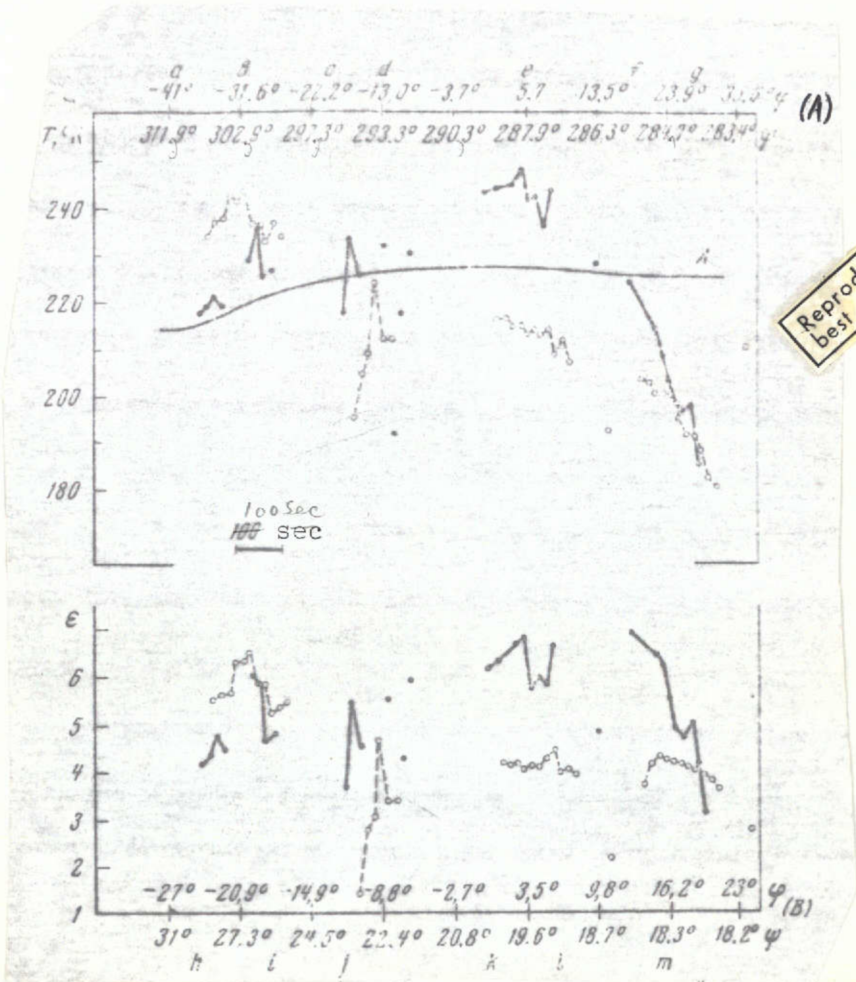

Fig. 3. Dependence of and T on measurements. Sessions of February 16 (A) and February 28, 1972 (B). (Designations are the same as in Fig. 2.)

a - Hellas Yaonis Regio, b - Mare Hadriacum, c - Iapagia, d - Denotria Crocea, e - Syrtis Major, f - Antigones, g - Meroe, h - Mare Erythraeum, i - Pyrrhae Regio, j - Margaritifier Sinus, k - Aram-Chryse, l - Oxia Palos, ia Oxia

Thus, as a result of the experiment, variations of temperature and permittivity of the Martian soil along the trail of the field of vision were determined.

The experience accumulated shows the prospects for radio-astronomical studies of Mars from on board its artificial satellite.

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